DESIGN OF MINI CNC MACHINE

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ABSTRACT

This thesis presents the design of Mini CNC Machine. This machine has 2axes, namely the Xand Y axis. Mini CNC machine is a small CNC machine that can operate like a normal CNC machine with a limited area of the machining. The objectives of this project are to develop the mini CNC Machine and to develop the software to control the machine. This thesis describes the development of the machine and the criteria needed to build the machine. The Mini CNC Machine is initially sketched by referring to the criteria that was decided. The criteria are the travel path length, type of linear motion, type of linear drive, motor and controller, and type of material that used. This machine's travel on the X axis is 15cm and Y axis is 15cm. The linear motion was used is a round linear rail and the linear drive used was a sliding element, lead nuts and lead screws. The motor used is a stepper motor with specification 2.1V and 3.0A. The frame material used is aluminium. This material is used because it is light in weight, easy to handle and machine and it is rust proof. The design was sketched using SolidWork software. For the next step is developing the wiring for motor and develop the program to control the stepper motor. The ULN 2803 is used to convert the signal from parallel port to specific winding energizing sequences to step the motor. The Visual Basic software is used to program the motor movement.

ABSTRAK

Tesis ini membentangkan reka bentuk Mini CNC Machine. Mesin ini mempunyai 2 paksi, iaitu paksi X dan Y. Mini CNC Machine adalah mesin CNC kecil yang boleh beroperasi seperti mesin CNC biasa dengan kawasan pemesinan yang terhad. Objektif projek ini adalah untuk membangunkan Mini CNC Machine dan untuk membangunkan perisian untuk mengawal mesin. Tesis ini menerangkan pembangunan mesin dan kriteria yang diperlukan untuk membina mesin. Mini CNC Machine mulanya dilakarkan dengan merujuk kepada kriteria yang telah diputuskan. Kriteria yang diputuskan adalah panjang laluan perjalanan, jenis gerakan linear, jenis pemacu linear, motor dan pengawal, dan jenis bahan yang digunakan. Perjalanan mesin ini pada paksi X 15cm dan paksi Y adalah 15cm. Pergerakan lelurus yang telah digunakan adalah rel linear yang bulat dan pemacu linear yang digunakan adalah elemen gelongsor, lead nuts dan lead skru. Motor yang digunakan ialah stepper motor dengan spesifikasi 2.1V dan 3.0A. Bahan bingkai yang digunakan ialah aluminium. Bahan ini digunakan kerana ia ringan berat badan, mudah untuk mengendalikan mesin dan ia adalah tahan karat. Reka bentuk yang dilakarkan menggunakan perisian SolidWork. Untuk langkah seterusnya membangunkan pendawaian untuk motor dan membangunkan program untuk mengawal stepper motor. ULN 2803 digunakan untuk menukar isyarat daripada parallel port kepada penggulungan urutan tenaga khusus untuk menggerakkan motor. Perisian Visual Basic digunakan untuk program pergerakan motor.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION OF PROJECT

Mini CNC machine is the machine that is similar to the usual CNC machine. Mini CNC machine is the small CNC machine that can operate like usual CNC machine but the area of the machining is limited. CNC machine is all about using the computer as a means to control machines that carves useful objects from solid block to material. For example, a CNC machine might begin with a solid block of aluminium, and then carved away just the right material to leave with a door handle.

There are many types of CNC machine. The common CNC machines are two-axis and three-axis CNC machine. The two- axis machine can move on vertical and horizontal only which are X and Y axis. Three-axis machine can do movement starting with three primary axis which are X, Y and Z axis. The Z axis is being parallel with the spindle (Micheal W. Mattson, 2010).

The CNC machine operation starts with the collecting the data from the programming that extract from the computer-aided design (CAD) and computer-aided manufacturing

(CAM). The programs produce the computer file and then will extract the command to operate the machine. The program will be transfer via post-processor and then be loaded into the CNC machine to start the machining. This is the flow of the CNC machine operation:

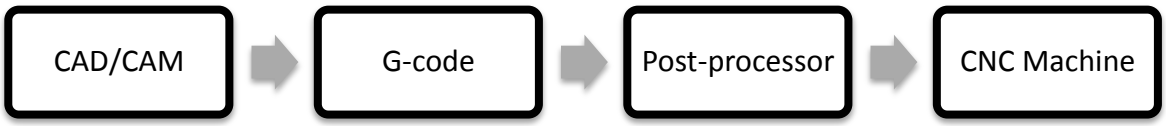

Figure 1.1: Flow of the CNC machine operation

The CNC machine is a system. To complete the system of CNC machine, there are 4 components which are mechanical design, drives module, system software and Automatically Programme Tool (APT) postprocessor.

For the mechanical design system, this part is the part of hardware of machine which is the part body. For the drive system, the command signal was received from microprocessor. Microprocessor is consisting of motors, amplifier units and a power supply. For the software system, it is generate the program to the CNC machine to start the movement of tools and workpiece. For the APT postprocessor, it was developed to produce the G-code and M-code that can be used by the CNC machine.

Figure 1.2: Flow of Mini CNC Machine

Besides that, CNC machine also include of wiring in order to connect the power to the machine. To complete the whole CNC machine, all the elements must be in the good condition and must put at the right place.

1.2 PROBLEM STATEMENT

Nowadays, the world are becoming highly technology with a lot of things become smaller and thinner. Even now the things especially in engineering and technology have the things in nano and micro size. Same goes to CNC Machine; this machine is now has variety of size in the market. All type of machine have own purpose, eventhough the size is big or small. The usual CNC machine can machine the big workpiece depends on the machine specification. The mini CNC machine only can machine the small workpiece depend on the machine specification. This project is about to overcome the problem of machining the small part. Even the usual CNC machine can machine the small workpiece, it will increase the time on setup the workpiece to the machine to get the accurate result. The mini CNC machine will give the small area of setup the workpiece and it will be easier to get the accurate place or result for the workpiece.

1.3 OBJECTIVES

The objectives of this study are:

- To develop the mini CNC machine
- To develop the software to generate the machine

1.4 SCOPE OF WORK

The scopes of this project are:

- Developing mini CNC machine with 3 axis
- Developing CNC programming
- Do wiring for the connection between machine and computer

1.5 PROJECT EXPECTATION

By the end of this project, student is expected to:

- Develop the Mini CNC Machine
- Learn to develop the program
- Learn how to connect the wiring of the circuit

CHAPTER 2

THEORETICAL REVIEW OF THE PROJECT

2.1 INTRODUCTION

The purpose of this chapter is to provide a review of past research efforts related to Mini CNC machine and the important component in developing this machine. From the related journal and article, the idea in CNC machine is developed before go further for the next chapter in completing this project.

2.2 MINI CNC MACHINE

Mini CNC Machine is the small CNC Machine that can operate same likes other CNC machine. This machine is designed for the specific dimension. The CNC machines can be divided into two groups, which are turning machines and milling machine. A turning machine is generally made up of a device that spins a workpiece at high speed and the tool is moved back and forth and in and out until the desired shape is achieved. A milling

machine is a machine that has spindle which is same as the router, with a special tool that spins and cuts in various directions and moves in three different directions along the X, Y, and Z axis. (Patrick Hood-Daniel, 2009)

A CNC machine with several unique features, such as simplicity and reliability, was developed for studying computerized numerical control and its associated software. The machine is especially useful for educational and research purposes, and it is easy to integrate with other manufacturing systems. It can also be used to introduce the CNC aspect of CAM systems without involving too many complexities that are present in commercial systems.

The three-axis machine is capable of continuous path movement. Its design is carried out with the following considerations in mind:

- Intended as an instruction or research kit, it should be small in size and lightweight.
- The worktable must have sufficient movement.
- The spindle head must be restrained to a single degree of freedom.
- A reduction must be given to the Z-drive for higher torque.

2.2.1 Specification of The Machine

From research and journal of A CNC Machining System for Education, The machine is designed to perform end milling for soft material such as soft aluminium alloy or plastics. The machine occupies approximately a 450 × 300 × 150 mm^3 volume and can machine a cube contained in a 60 mm^3 volume. The maximum cutter diameter is 8 mm. The machine consists of 42 parts, which are simple in design and easy to assemble.

The movements are limited to 60-mm in the X and Y directions and 70-mm in the Z direction. The spindle speed that can be use is between 100 rpm to 4000 rpm. The maximum feed rate of the machine is 100mm/min. The maximum dept of cut is 0.3mm. The maximum torque along X and Z axis is 6Kg-cm. In this journal, he said that, the

complete system can be divided into four modules which are mechanical design, drives module, system software and the APT postprocessor. (A. A. Tseng, 1985)

CNC system consists of three basic components which are Part program, Machine Control Unit (MCU) and Machine tool (lathe, drill press, milling machine). The part program is a detailed set of commands to be followed by the machine tool. Each command specifies a position in the Cartesian coordinate system (x,y,z) or motion (workpiece travel or cutting tool travel), machining parameters and on/off function. The machine control unit (MCU) is a microcomputer that stores the program and executes the commands into actions by the machine tool. The MCU consists of two main units: the data processing unit (DPU) and the control loops unit (CLU). The machine tool could be one of the following: lathe, milling machine, laser, plasma and coordinate measuring machine. (B. S. Pabla, 1994)

From the other source from the website, the mini CNC Machine is that is build in this project uses Dremel rotary tool. The movements for this machine are limited to 150-mm in the X direction, 200-mm in Y directions and 50-mm in the Z direction. The feed rate of this machine is 6mm/s. The accuracy is about 0.25mm. (Contraptor)

2.2.2 The Fundamental Of The Mini CNC Machine

In these four modules, he elaborates the part one by one which is module by module. First module is about the mechanical design. Mechanical design of the machine involves conceptual of overall configuration of the machine, drafting and design analysis made to satisfy geometrical and force constrain. In this module, the machine specification is identified and the power for machining aluminium is calculated.

The second module is the drive module. This module show that the controller of the machine which is microprocessor that is receive the command signals. Drive module is consisting of motors, amplification units, and a power supply. The control signals are the first generated by the microprocessor to determine the direction of rotation of the motor.

The third module is system software. The system software can be defined as an instruction set required executing the functions of the system through a set physical component. The software system is designed to generate automatic stops for the tool and workpiece movements. This is done because the unit operates in the open loop mode.

Lastly, the fourth module is the Automatically Programmed Tool (APT) postprocessor. APT is a language that is used to control a variety of operations in machining and that is generating from the CAD/CAM software system. The APT postprocessor was developed to produce G-codes and M-codes that can be used by CNC machine constructed from the APT files produced by commercial CAD software.

From the book CNC Machines by B. S. Pabla, M. Adithan, they state that there are some features in CNC machine tools (B. S. Pabla, 1994). The features are:-

- The part programme can be input to the controller unit through key-board or the paper tape can be read by the tape reader in control unit
- The part programme once entered in to the computer memory can be used again and again
- The part programme can be edited and optimised at the machine tool itself
- The input information can be reduced to a great extent with the use of special sub-programmes developed for repetitive machining sequence
- The CNC machines have the facility for proving the part programme without actually running it on the machine tool
- CNC control unit allows compensation for any changers in the dimension of cutting tool
- With the CNC control system, it is possible to obtain information on machine utilisation which is useful to management

The combined characteristics of the machine tool and the control determine the precision of positioning. Three critical measures of precision are resolution, accuracy and repeatability. Control resolution (BLU) is the distance separating two adjacent points in the axis movement (the smallest change in the position) . The electromechanical components of

the positioning system that affect the resolution are the leadscrew pitch, the gear ratio, and the step angle in the stepping motor (open loop) or the angle between the slots in the encoder (closed-loop).

Accuracy of a CNC system depends on the resolution, the computer control algorithms, and the machine inaccuracies. The inaccuracy due to the resolution is considered to be (1/2) BLU on the average. The control algorithm inaccuracy is due to the rounding off the errors in the computer which is insignificant. Repeatability is a statistical term associated with accuracy. It refers to the capability of a positioning system to return to a programmed point, and is measured in terms of the errors associated with the programmed point. The deviation from the control point (error) usually follows a normal distribution in which case the repeatability may be given as +/- 3a where a is the standard deviation. The repeatability is always better than the accuracy. The mechanical inaccuracy can be considered as the repeatability.

2.2.3 Motor

The signals from the amplifiers are given to the stepper motors to produce movements in the X-, Y-, and Z-directions. An AC/DC motor is used to drive the spindle. The amplifier units form the intermediate stage between the controller and the drives. Control signals are first generated by the microprocessor to determine the direction of rotation of the motor. The number of pulses per second determines the actual speed of rotation. The current of the signal issued by the microprocessor must be sufficiently amplified before it is fed to the stepping motors which actuate the axis of motion. The drive module must be capable of supplying the output without distorting the switching sequence required to run the stepping motor. The stepper motor shaft is coupled to a screw rod that is connected to the work slide through a nut. The rotation of the stepper motor shaft results in linear motion of the slide.

The pulse rate determines the cutting velocity. The stepping motors used for this system are the four-phase type. The common terminals of the stepper motor are fed with a 7.5V

supply for the 'X' and 'Z' motors and with a 6 V supply for the 'Y' motor. The variable resistance may be used to get the correct drop across the corresponding terminals. The microprocessor chip acts as a buffer while double inverting the logic levels supplied to it from the microprocessor. The main drive corresponds to the motor that drives the spindle. The requirement for the main drive is that it must be capable of providing varying speeds of rotation corresponding to the different cutting velocities needed for machining various materials. An auto transformer capable of supplying variable voltage is connected to the AC/DC drive motor. Altering the voltage gives a new speed. The autotransformer is calibrated in terms of spindle speed.

The open-loop control means that there is no feedback and uses stepping motors for driving the leadscrew. A stepping motor is a device whose output shaft rotates through a fixed angle in response to an input pulse. The accuracy of the system depends on the motor's ability to step through the exact number. The frequency of the stepping motor depends on the load torque. The higher the load torque, lower would be the frequency. Excessive load torque may occur in motors due to the cutting forces in machine tools. Hence this system is more suitable for cases where the tool force does not exist. The stepping motor is driven by a series of electrical pulses generated by the MCU. Each pulse causes the motor to rotate a fraction of one revolution.

Closed -loop NC systems are appropriate when there is a force resisting the movement of the tool/workpiece. The encoder consists of a light source, a photo detector, and a disk containing a series of slots. The encoder is connected to the leadscrew. As the screw turns, the slots cause the light to be seen by the photo detector as a series of flash which are converted into an equivalent series of electrical pulses which are then used to characterize the position and the speed. The equations remain essentially the same as open-loop except that the angle between the slots in the disk is the step angle. Both the input to the control loop and the feedback signals are a sequence of pulses, each pulse representing a BLU unit. The two sequences are correlated by a comparator and gives a signal, by means of a digital-to-analog converter, (a signal representing the position error), to operate the drive motor (DC servomotor).

2.2.4 Software system

The software involves the building of an interpreter for the part program. The part program executed by the microprocessor consists of a series of instructions. Each instruction comprising a string of binary digits is decoded by the microprocessor and is then executed. The microprocessor requires these instructions to be written in Op-codes. An Op-code is an instruction that is composed of hexadecimal characters. The interpreter translates the G-codes into equivalent Op-codes.

The software for the system is designed to generate automatic stops for the tool and workpiece movements. This is done because the unit operates in the open loop mode. The backlash in the screw rod is estimated and the software is corrected for this error. The system software is developed by adopting the modular programming format. A module may be termed as a subroutine that forms a part of the main program. Every module comprises a set of general purpose instructions that can be accessed when required during the course of execution of the program. All the G-codes require stepping motors to be switched on and off. One module is set apart for switching on the stepper motors. This module is accessed by all the 'G' functions which mean that this module does not belong to any particular G-code.

Initially, the system software is loaded in random access memory (RAM) of the microprocessor for testing purposes. After the credibility of the program has been established, the addresses of the Op-codes are located in the ROM (read only memory) area designated by the makers of the microprocessor kit. The programs are then loaded into an erasable programmable read only memory (EPROM) to form a permanent part of the system, until a hardware erasure is affected. This is in contrast to the operation of a RAM, which loses its contents once the system is switched off.

The EPROM instructions are not accessible to the user. By removing the EPROM from the system software for milling, and inserting another EPROM into the microprocessor, which perhaps has lathe system software, the controller that is used to control a CNC

milling machine can then be used to control a CNC lathe. Once the software has been developed and tested, the manufacture of the system proves easy because the general purpose microprocessor loaded with this software in ROM becomes specific to the machine tool.

The machine operates in two modes - the manual mode and the automatic mode. The manual mode allows the motion in the machine to be controlled by manually pressing the appropriate keys. The automatic mode allows the execution of the instructions in the part program.

First, the machining parameters are determined. Second, the optimal sequence of operations is evaluated. Third, the tool path is calculated. Fourth, a program is written. Each line of the program, referred to as a block, contains the required data for transfer from one point to the next.

A typical line for a program is given below.

N100 G91 X -5.0 Y7 .0 F100 S200 T01 M03 (EOB)

The significance of each term is explained below.

Sequence Number, N. Consisting of typically three digits, its purpose is to identify the specific machining operation through the block number particularly when testing a part program. Preparatory Function, G. It prepares the MCU circuits to perform a specific operation. The G-codes. G91 implies incremental mode of operation. Dimension Words consist of Distance dimension words, X, Y, Z, Circular dimension words, I, J, K for distances to the arc center and angular dimensions, A, B. C

2.2.5 Advantages and disadvantages of CNC Machine

In this book also state about advantages and disadvantages of CNC machines. The advantages of CNC machines are reduced lead time, elimination of operator errors, operator activity, lower labour cost, smaller batches, longer tool life, elimination of special jigs and fixtures, flexibility in changes of component design, reduced inspection, less scrap and accurate costing and scheduling. The specific advantages of the CNC system are: 1) the simplicity--the operating principles of the machine and control system can be very easily understood, 2) since very few transmission elements are used, the reliability of the system is high, and 3) not many instruction systems of this type are currently available in the marketplace. (A. A. Tseng, 1985)

The disadvantages of CNC machines are higher investment cost, higher maintenance cost, costlier CNC personnel and planned support facility.

CHAPTER 3

FLOW WORK AND METHOD OF THE PROJECT

3.1 INTRODUCTION

Flow work and method of the project is generally a guideline for solving a problem. In this chapter, the methods of conducting the project are briefly discussed which involved specific components such as tasks, techniques and tools. The framework of flow work must clearly clarify in order to make sure the project will run smoothly and the objectives of project are able to achieve successfully.

3.2 GUIDELINE METHODOLOGY

The start of the flow work is to understand the fundamental of the Mini CNC machine. After doing some research and study about the Mini CNC machine, the next step that is needed to do is design the machine according to the understanding of the mini CNC machine concept. The designing of the machine including with the wiring connection and the software that is use to generate the program. Develop the machine base of the design that has been drawn.

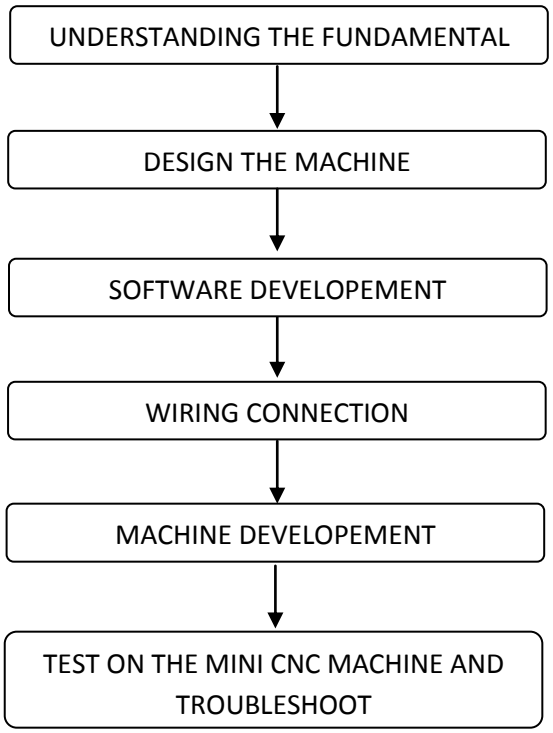

Figure 3.1: Flowchart of the methodology

3.2.1 Understanding the fundamental

In this stage, the understanding of the machine's concept is needed. The basic of the project is very important. To understand the concept of the project, the research on the past journals, books, articles, and the experiment of the area of machine development.

In chapter 2, the theoretical reviews of the project, are described about the fundamental of the Mini CNC Machine. The resource is collect from the books which are CNC Machines by B. S. Pabla, M. Adithan, Programming of CNC Machines: Student Workbook by Ken Evans, CNC Programming: Principles and Applications by Micheal W. Mattson, Mike Mattson and Build Your Own CNC Machine by Patrick Hood-Daniel, James Floyd Kelly.

The other resources are from journal and articles which are about the Mini CNC Machine. For example, A CNC Machining System for Education by A.A.Tseng, S.P.Kolluri and P.Radhakrishnan, Computer Numerical Control by Dr. Aseel A.Al-Hamdany, and Evaluation of Performance Criteria of CNC Machine Tool Drive System by Venkatram Ramachandran. All the resources are combined together then summarize it into chapter 2.

3.2.2 Design the machine

In this stage, the machine will be design to the desire design. The initial design will be drafting or sketching then when the design is approve. Then step to the next stage of design which is draw the design using the software SolidWork. Finally, come out with the complete drawing.

Before start the sketching, there are some criteria that must be decided. Firstly, decide the length of travel. The length of travel is the length of X, Y, and Z axis move from one point to the other point. The X axis move left - right, Y axis move front - back, Z axis move up – down. The travel length that have been decided is X axis 15cm, Y axis 15cm and Z axis 5cm.